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27-5 Space-Conserving Antennas

In many cases it is desired to undertake a considerable amount of operation on the 80-meter or 40-meter band, but insufficient space is simply not available for the installation of a half-wave radiator for the desired frequency of operation.

This is a common experience of those who are forced to reside in an apartment house or in a bungalow court. The shortened Marconi antenna operated against a good ground ran be used under certain conditions, but the shortened Marconi is notorious for the production of broadcast interference. and a good ground connection is usually completely unobtainable in an apartment house.

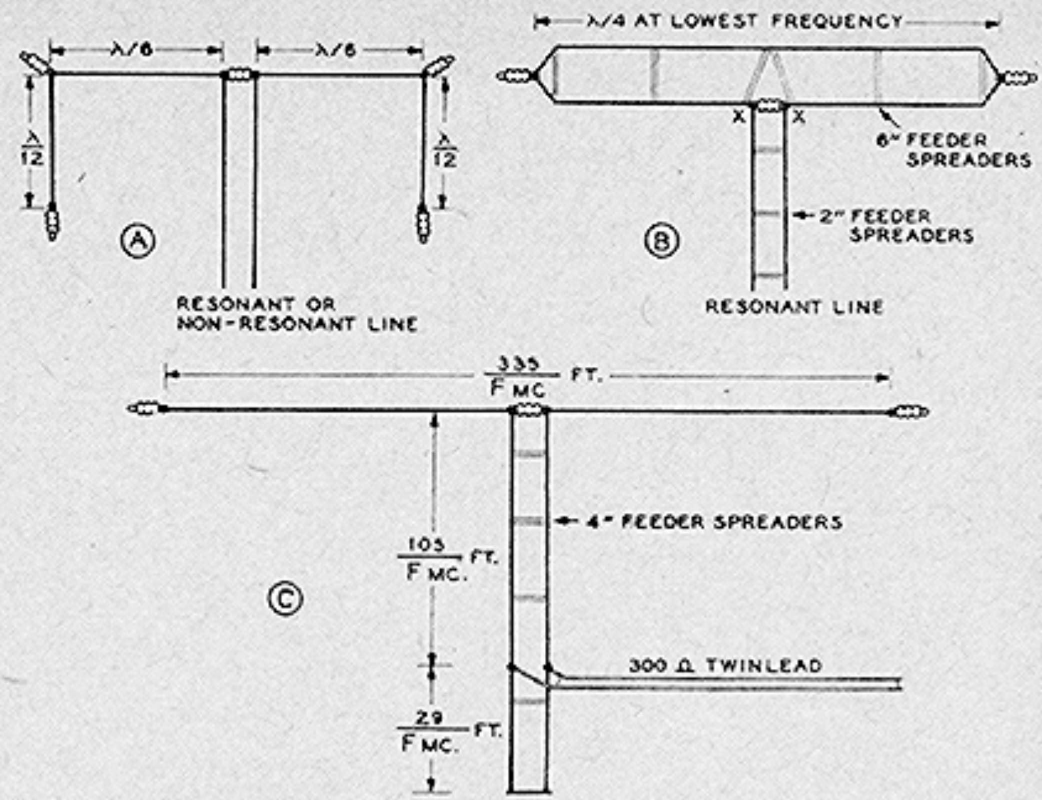


Figure 7.

THREE EFFECTIVE SPACE CONSERVING ANTENNAS.

The arrangements shown at (A) and (B) are satisfactory where resonant feed line can be used. However, non-resonant 75-ohm feed line may be used in the arrangement at (A) when the dimensions in wavelengths are as shown. In the arrangement shown at (B) low standing waves will be obtained on the feed line when the overall length of the antenna is a half wave. The arrangement shown at (C) may be tuned for any reasonable length of flat top to give a minimum of standing waves on the transmission line.

Essentially, the problem in producing an antenna for lower frequency operation in restricted space is to erect a short radiator which is balanced with respect to ground and which is therefore independent of ground for its operation. Several antenna types meeting this set of conditions are shown in Figure 7. Figure 7A shows a conventional center-fed doublet with bent-down ends. This type of antenna can be fed with 75 Ohm twinlead in the center, or it may be fed with a resonant line for operation on several bands. The overall length of the radiating wire will be a few per cent greater than the normal length for such an antenna since the wire is bent at a position intermediate between a current loop and a voltage loop. The actual length will have to be determined by the cut-and-try process due to the increased effect of interfering objects on the effective electrical length of an antenna of this type.

Figure 7B shows a method for using a two wire doublet on one half of its normal operating frequency. It is recommended that spaced open conductor be used for the radiating portion of the "folded dipole" rather than 300-ohm twinlead as is commonly used when operation on only one frequency is desired. The reason for this recommendation lies in the fact that the two wires of the flat top are not at the same potential throughout their length when the antenna is operated on one-half frequency. Twinlead may be used for the feeder line if operation on the frequency where the flat top is one-half wave in length is most common, and operation on one-half frequency is infrequent. However, if the antenna is to be used primarily on one-half frequency as shown it should be fed by means of an open-wire line. If it is desired to feed the antenna with a nonresonant line, a quarter-wave stub may be connected to the antenna at the points X, X in Figure 7B. The I stub should be tuned and the transmission line connected to it in the normal manner.

The antenna system shown in Figure 7C may he used when not quite enough length is available for a full half-wave radiator. The dimensions in terms of frequency are given on the drawing. An antenna of this type is 95 feet long for operation on 3600 kc. and 86 feet long for operation on 3900 kc. This type of antenna has the additional advantage that it may be operated on the 7-Mc. and 14-Mc. bands, when the flat top has been cut for the 3-Mc. band, simply by changing the position of the shorting bar and the feedline on the stub. The procedure is discussed in more detail in Section 27-6 of this chapter.

A sacrifice which must be made when using a shortened radiating system, as for example the types shown in Figure 7, is in the bandwidth of the radiating system. The frequency range which may he covered by a shortened antenna system is approximately in proportion to, the amount of shortening which has been employed. For example, the antenna system shown in Figure 7C may be operated over the range from 3800 kc. to 4000 kc. without serious standing waves on the feeder line. If the antenna had been made full length it would be possible to cover about half again as much frequency range for the same amount f mismatch on the extremes of the frequency range.

27-6 Multi-Band Antennas

The availability of a multiband antenna is a great operating convenience for an amateur station. In most cases it will be found best to install an antenna which is optimum for the band which is used for the majority of the available operating time, and then to have an additional multi-band antennas which may be pressed into service for operation on another band when propagation conditions on the most frequently used band are not suitable. Most amateurs use, or plan to install, at least one directive array for one of the higher-frequency hands, but find that an additional antenna which may be used on the 3.5-Mc. and 7.0-Mc band or even up through the 28-Mc. band is almost indispensable.

The choice of a multi-band antenna depends upon a number of factors such as the amount of space available, the band which is to be used for the majority of operating with the antenna, the radiation efficiency which is desired, and the type of antenna tuning network to be used at the transmitter. A number of recommended types for use under differing conditions are illustrated in Figures 8 through 11.

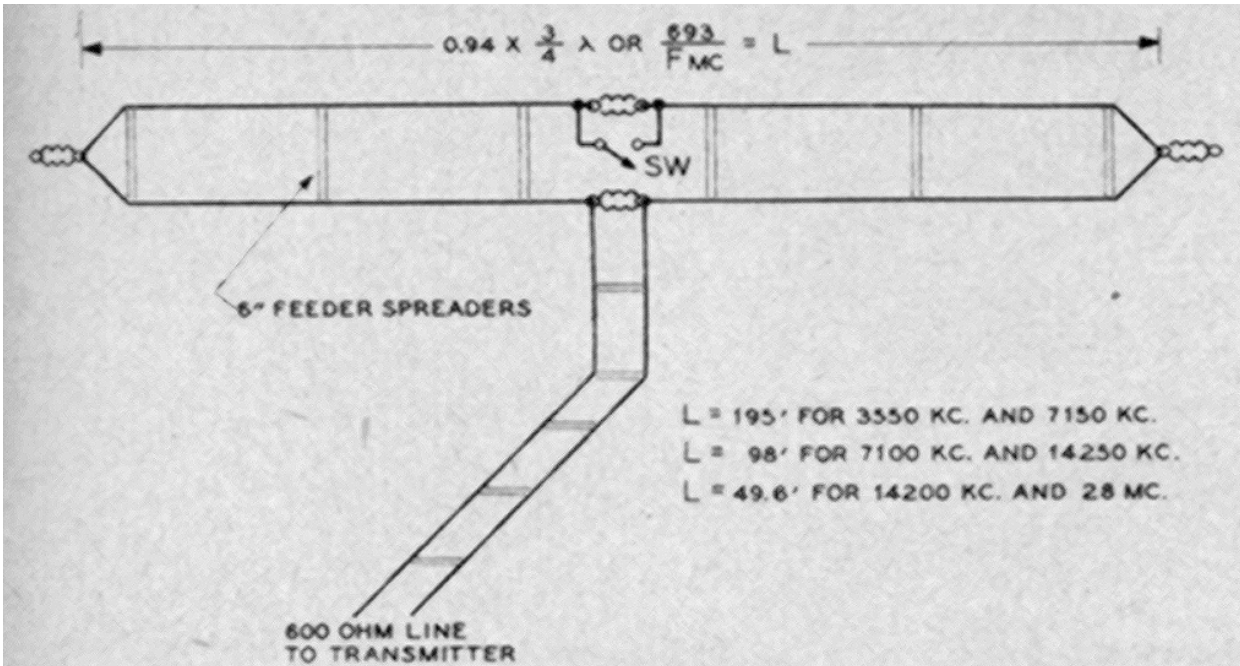


Figure 8.

THE THREE-QUARTER WAVE FOLDED DOUBLET.

This antenna arrangement will give very satisfactory operation with a 600-ohm feed line for operation with the switch open on the fundamental frequency and with the switch closed on twice frequency.

The 3/4 -Wave Doublet. Figure 8 shows an antenna type which will be found to be very effective when a moderate amount of space is available, when most of the operating will be done on one band with occasional operation on the second harmonic. The system is quite satisfactory for use with high-power transmitters since a 600-ohm non-resonant line is used from the antenna to the transmitter and since the antenna system is balanced with respect to ground. With operation on the fundamental frequency of the antenna where the flat top is 3/4-wave long the switch SW is left open. The system affords a very close match between the 600-ohm line and the feed point of the antenna. Kraus has reported a standing-wave ratio of approximately 1.2 to 1 over the 14-Mc. band when the antenna was located approximately one-half wave above ground (Radio, June 1939).

For operation on the second harmonic the switch SW is closed. The antenna is still an effective radiator on the second harmonic but the pattern of radiation will be different from that on the fundamental and the standing-wave ratio on the feed line will be greater.

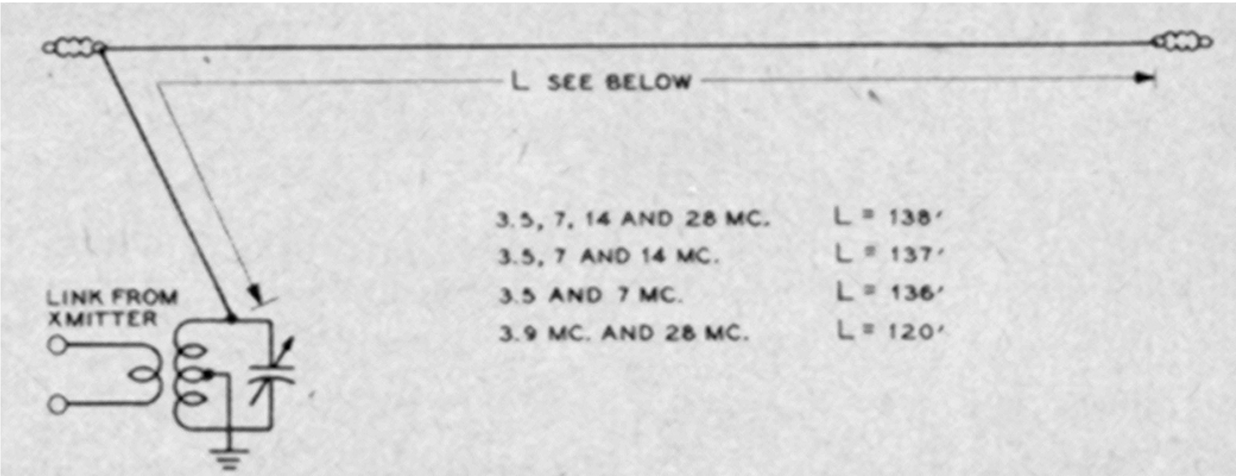
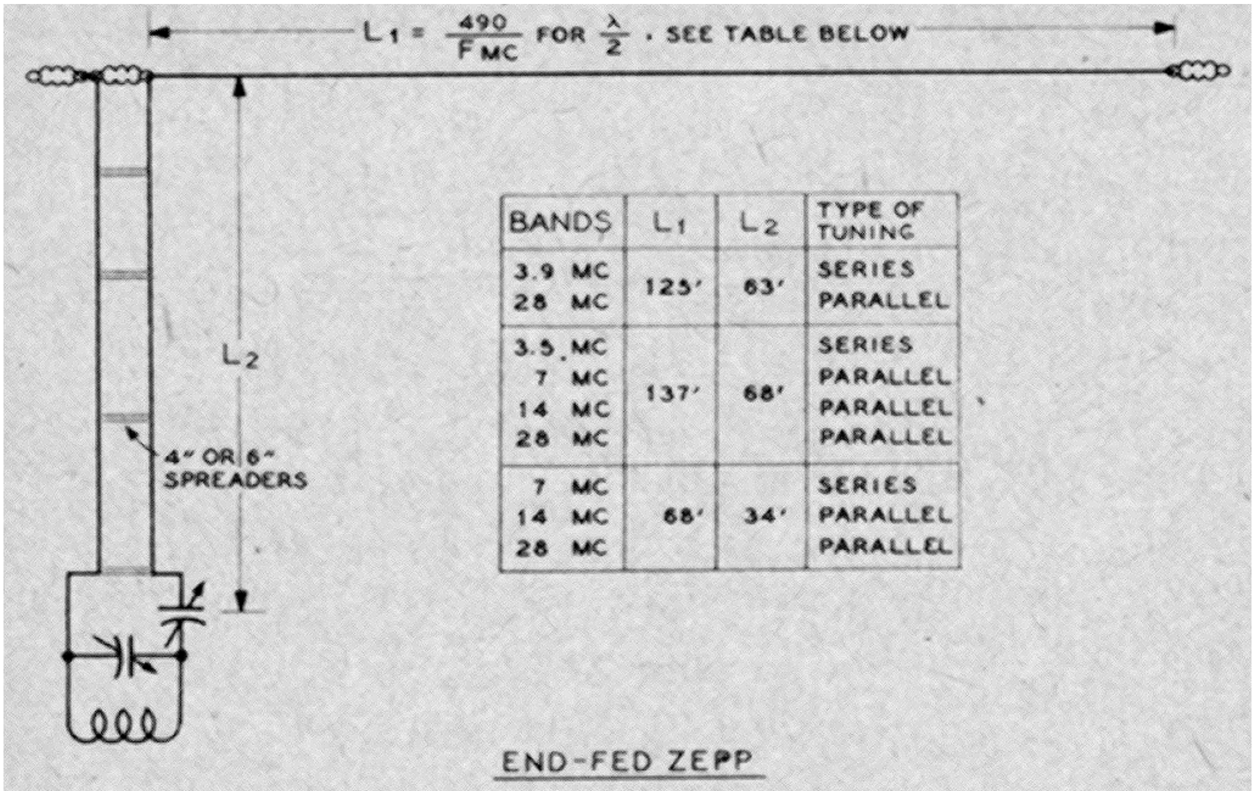


Figure 9.
RECOMMENDED LENGTHS AND METHOD OF FEED FOR THE END-FED HERTZ ANTENNA.

The End-Fed Hertz. The end-fed Hertz antenna shown in Figure 9 is not as effective a radiating system as many other antenna types, but it is particularly convenient when it is desired to install an antenna in a hurry for a test, or for field-day work. The flat top of the radiator should be as high and in the clear as possible. In any event at least three quarters of the total wire length should be in the clear. Dimensions for optimum operation on various amateur bands are given in addition in Figure 9.

The End-Fed Zepp. The end-fed Zepp has long been a favorite for multi-band operation. It is shown in Figure lo along with recommended dimensions for operation on various amateur band groups. Since this antenna type is an unbalanced radiating system, its use is not recommended ~with high-power transmitters where interference to broadcast listeners is likely to be encountered. The r-f voltages encountered at the end of zepp feeders and at points an electrical half-wave from the end are likely to be quite high Hence the feeders should be supported an adequate distance from surrounding objects and sufficiently in the clear so that a chance encounter between a passerby and the feeder is unlikely.

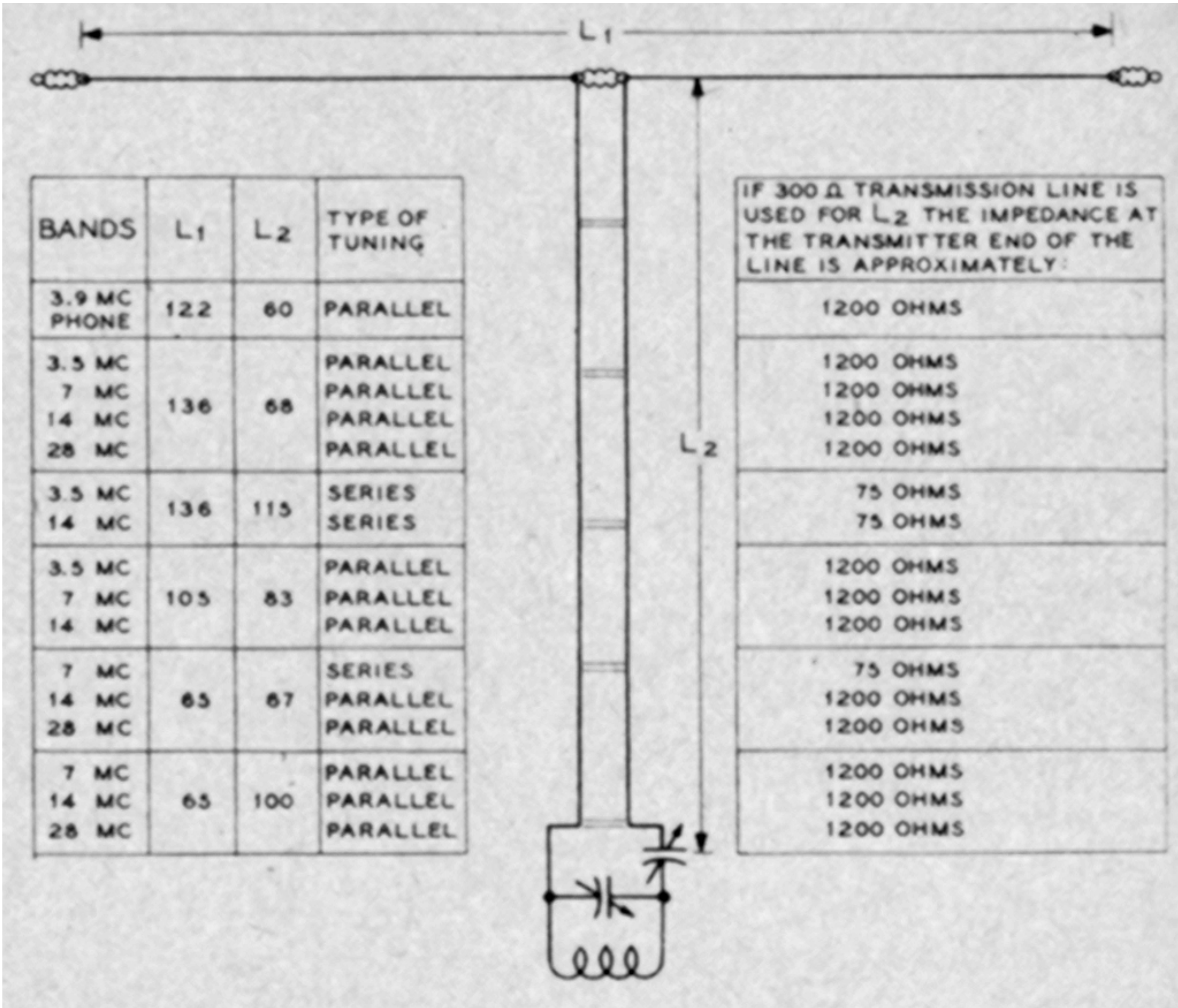


BANDS	L1	L2	TYPE OF TUNING
3.9 MC 28 MC	125'	63'	SERIES PARALLEL
3.5 MC 7 MC 14 MC 28 MC	137'	68'	SERIES PARALLEL PARALLEL PARALLEL
7 MC 14 MC 28 MC	68'	34'	SERIES PARALLEL PARALLEL

Figure 10.

The coupling coil at the transmitter end of the feeder system can be directly inductively coupled to the transmitter output circuit but the use of a grounded coupling link between the output tank of the transmitter and the feeder-tuning coil is strongly-recommended in order to reduce harmonic radiation. Transmitter-to-feed line coupling methods have been discussed in detail in Chapter 10.

The Center-Fed Multi-Band Antenna. Several types of center-fed antenna systems are shown in Figure 11. If the feed line is made up in the conventional manner of no. 12 or no. 14 wire spaced 4 to 6 inches, the antenna system is sometimes called a center-fed zepp. With this type of feeder the impedance at the transmitter end of the feeder varies from about 70 ohms to approximately 5000 ohms, the same as is encountered in an end-fed zepp antenna. This great impedance ratio requires provision for either series or parallel tuning of the feeders at the transmitter, and involves quite high r-f voltages at various points along the feed line.



BANDS	L1	L2	TYPE OF TUNING	IF 300 Ω TRANSMISSION LINE IS USED FOR L2 THE IMPEDANCE AT THE TRANSMITTER END OF THE LINE IS APPROXIMATELY:
3.9 MC PHONE	122	60	PARALLEL	1200 OHMS
3.5 MC 7 MC 14 MC 28 MC	136	68	PARALLEL PARALLEL PARALLEL PARALLEL	1200 OHMS 1200 OHMS 1200 OHMS 1200 OHMS
3.5 MC 14 MC	136	115	SERIES SERIES	75 OHMS 75 OHMS
3.5 MC 7 MC 14 MC	105	83	PARALLEL PARALLEL PARALLEL	1200 OHMS 1200 OHMS 1200 OHMS
7 MC 14 MC 28 MC	65	67	SERIES PARALLEL PARALLEL	75 OHMS 1200 OHMS 1200 OHMS
7 MC 14 MC 28 MC	65	100	PARALLEL PARALLEL PARALLEL	1200 OHMS 1200 OHMS 1200 OHMS

CENTER-FED ANTENNA

Figure 11.

If the feed line between the transmitter and the antenna is made to have a characteristic impedance of approximately 300 ohms the excursions in end-of-feeder impedance are greatly reduced. In fact, the impedance then varies from approximately 75 ohms to 1200 ohms. With this much lowered impedance variation it is usually possible to use series tuning on all bands, or merely to couple the antenna directly to the output tank circuit or the harmonic reduction circuit without any separate feeder tuning provision.

There are four practicable types of transmission line which can give an impedance of approximately 300 ohms. The first is, obviously, 300 ohm twinlead. Twinlead of the receiving type may be used as a resonant feed line in this case, but its use is not recommended with power levels greater than perhaps 100 watts, and it should not be used when lowest loss in the transmission line is desired. Although twinlead is quite satisfactory for a nonresonant line, it has not been designed for application as a resonant line. The second type is a two-wire air-spaced line with large conductors and close spacing. The ratio of conductor spacing to conductor radius for a characteristic impedance of 300 ohms is 12.22. In other words, no. 10 wire should be spaced 0.6", no. 8 wire should be spaced 0.79", 3/16" copper tubing should be spaced about 1.14", and 1/4-inch copper tubing should be spaced 1.53". Johnson no. 132 2" feeder spreaders have a notch cut in the side for use with 1/4-inch copper tubing at 1-1/2" spacing for making up a 300 ohm line.

The third type of transmission line which may be used to obtain an impedance of 300 ohms is the standard cross-connected four-wire air-spaced line. In this case to obtain, from the equation:

$$Z_o = 138 \log (S/r) - 20.8$$

an impedance of 300 ohms requires a ratio of conductor spacing to conductor radius of 211.2. This high ratio requires the use of rather small wires or rather large spacings. Number 18 wires would be spaced 4" on the sides of the square, or equally about a 5.65" diameter circle.

Probably the most satisfactory method for obtaining a low loss 300-ohm line of simple construction is to use a four-wire side-connected transmission line. This type of transmission line is constructed the same as a conventional cross-connected four-wire line but adjacent pairs of wire are strapped together at the ends (make sure that the same pair is strapped at each end). This type of transmission line has not been very commonly used in the past but it lends itself particularly to the construction of transmission lines with impedances in the range between 260 ohms (above which the four-wire cross-connected line becomes difficult mechanically) and 400 ohms (below which the two-wire line becomes mechanically difficult to construct).

The equation for the characteristic impedance of such a line where the four wires are placed on the corners of a square is:

$$Z, = 138 \log (S/r) + 20.8$$

where S is the spacing between adjacent wires and r is the radius of the wires. Inspection of the equation shows that the form of the equation is the same as that for the cross-connected four-wire line except that a plus sign has been substituted for the minus sign between the last two terms. This means that if we change the end-strap connections on a four-wire cross-connected line to make it an adjacent-connected line, the impedance of the line will be raised by 41.6 ohms. The actual ratio of spacing to radius for 300 ohms impedance using this type of line is 105.5. It will be noticed that this ratio is exactly half that required for the same value of impedance using a cross-connected line; this fact will be found true in all cases when comparing the two methods of connection for a four-wire line--the ratio of spacings for a cross-connected line is exactly twice that for an adjacent-connected line having the same impedance.

Folded Flat-Top Dual-Band Antenna. As has been mentioned earlier, there is an increasing tendency among amateur operators to utilize rotary or fixed arrays for the 14-Mc. band and those higher in frequency. In order to afford complete coverage of the amateur bands it is then desirable to have an additional system which will operate with equal effectiveness on the 3.5-Mc. and 7-Mc. bands, but this low-frequency antenna system will not be required to operate on any bands higher in frequency than the 7-Mc. band. The antenna system shown in Figure 12 has been developed to fill this need.

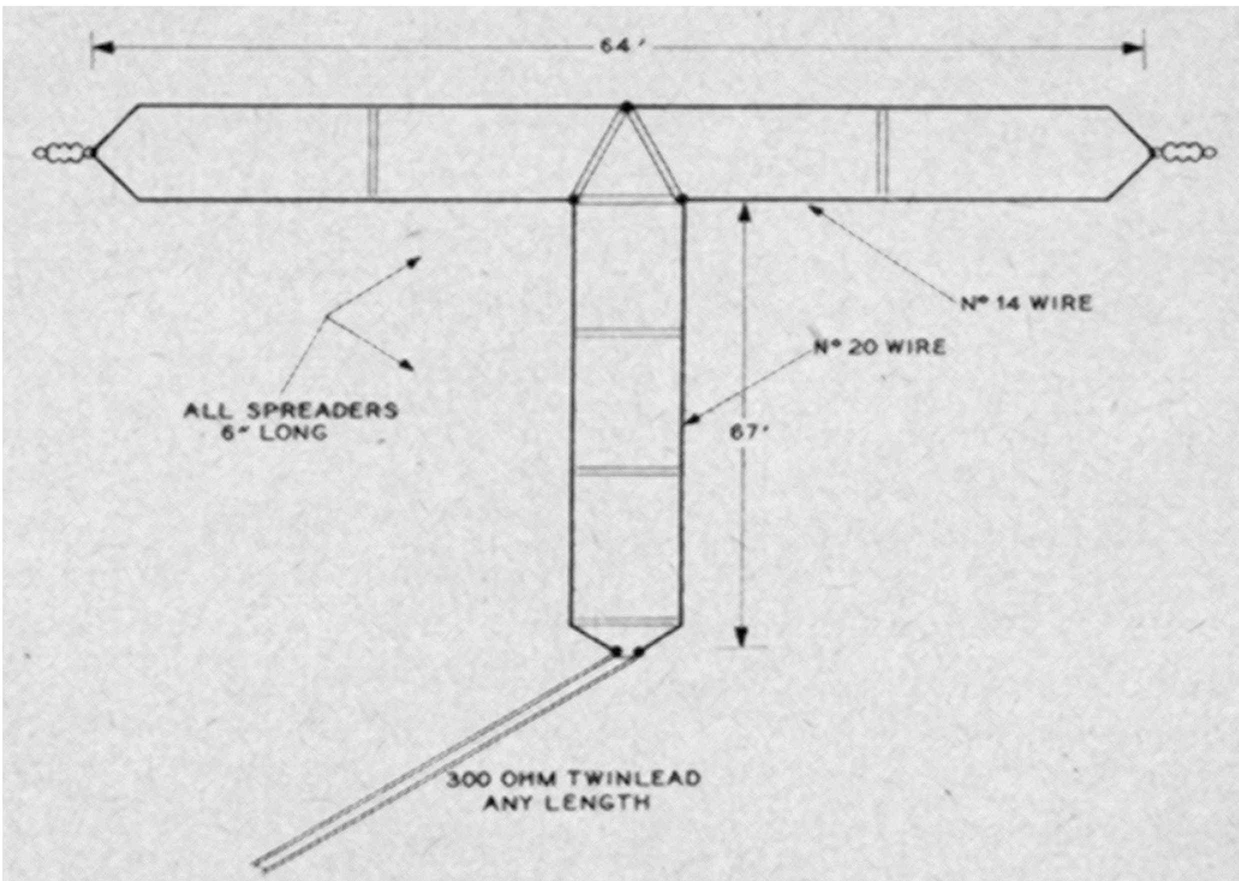


Figure 12.
FOLDED-TOP DUAL-BAND ANTENNA.
This excellent space-conserving two-band antenna is described in detail in the accompanying text.

The system consists essentially of an open-line folded dipole for the 7-Mc band with a special feed system which allows the antenna to be fed with minimum standing waves on the feed line on both the 7-Mc and 3.5-Mc bands. The feed-point impedance of a folded dipole on its fundamental frequency is, as has been discussed in Section 27-1, approximately 300 ohms. Hence, the 300-ohm twinlead shown in Figure 12 can be connected directly into the center of the system for operation only on the 7-Mc band and standing waves for the feeder will be very small. However, transmission-line theory teaches us that it is possible to insert an electrical half-wave of transmission line of any characteristic impedance into a feeder system such as this and the impedance at the far end of the line will he exactly the same value of impedance which the half-wave line sees at its termination. Hence, this has been done in the antenna system shown in Figure 12; an electrical half-wave of line has been inserted between the feed point of the antenna and the 300-ohm transmission line to the transmitter. The characteristic impedance this additional half-wave section of transmission line has been made about 715 ohms, but since it is an electrical half wave long at 7 Mc and operates into a load of 300 ohms at the antenna, the 300-ohm twinlead at the bottom of the half-wave section still sees an impedance of 300 ohms. The additional half-wave section of transmission line introduces a negligible amount of loss since the current flowing in the section of line is the same which would flow in a 300-ohm line at each end of the half-wave section. And at all other points it is less than the current which would flow in a 300-ohm Line, since the effective impedance is greater than 300 ohms in the tenter of the half-wave section. This means that the loss is less than it would be in an equivalent length of 300-ohm twinlead, since this type of manufactured transmission line is made up of conductors which are equivalent to no. 20 wire.

So we see that the added section of 715-ohm line has substantially no effect on the operation of the antenna system on the 7-Mc hand. However, when the flat top of the antenna is operated the 3.5-Mc band, the feed~point impedance of the flat-top is approximately 2600 ohms. Since the section of 715-ohm transmission line is an electrical quarter-wave in length on the 3.5-Mc band, this section of line will have the effect of transforming the approximately 2600 ohms feed-point impedance of the antenna down to an impedance of 200 ohms. This will approximately match the 300-ohm impedance of the twinlead transmission line from the transmitter to the antenna system.

The antenna system of Figure 12 operates with very low standing waves over the entire 7-Mc band, and it will operate with low standing waves from 3500 to 3800 kc. in the 3 5.Mc. hand and with sufficiently low standing-wave ratio so that it is quite usable over the entire 3.5-Mc band.

This antenna system, as well as all other types of multi-band antenna systems, must he used in conjunction with some type of harmonic-reducing antenna tuning network, even though the system does present the convenient impedance value of 300 ohms on both bands. Harmonic-reducing antenna-coupling networks have been discussed in detail in Chapter 10, Section 10-4.